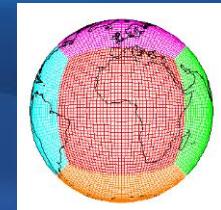


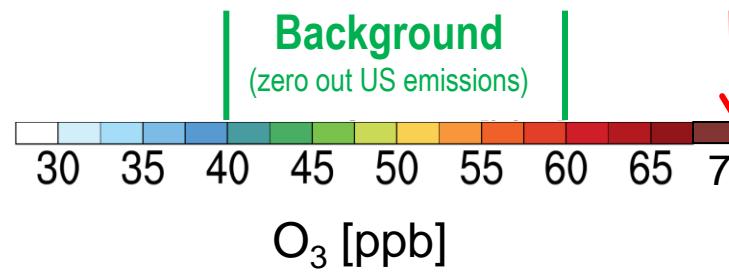
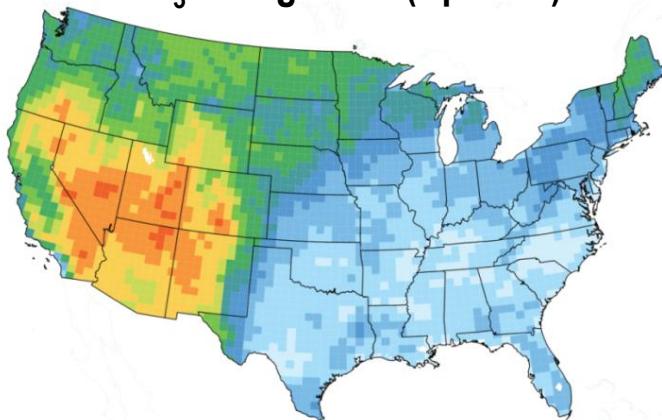
Role of climate, the stratosphere and emissions on U.S. surface O₃ trends and extremes

MEIYUN LIN
(PRINCETON/NOAA GFDL)



GFDL-AM3
(Nudged to NCEP winds)

U.S. O₃ background (Apr-Jun)

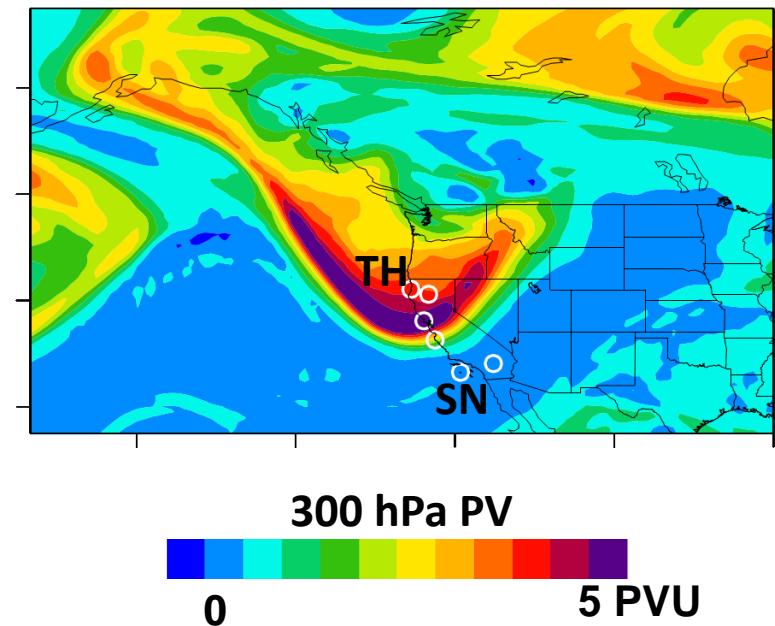


New US O₃
Standard

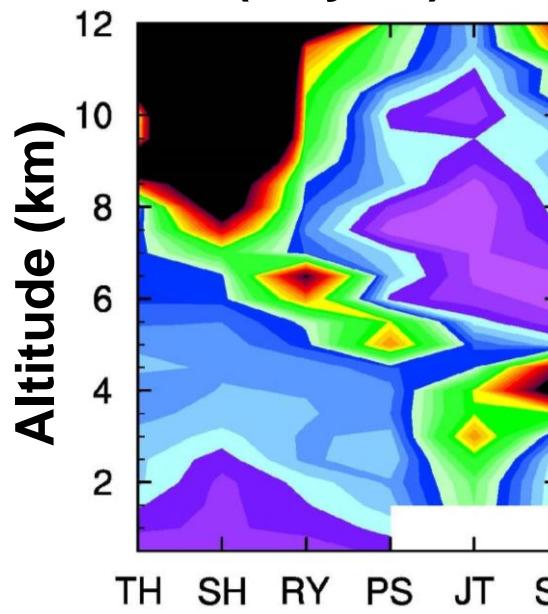


Deep stratospheric O₃ intrusions over the western U.S.

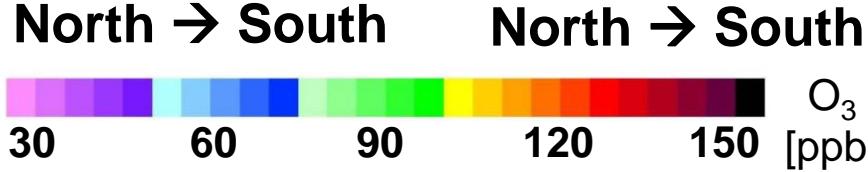
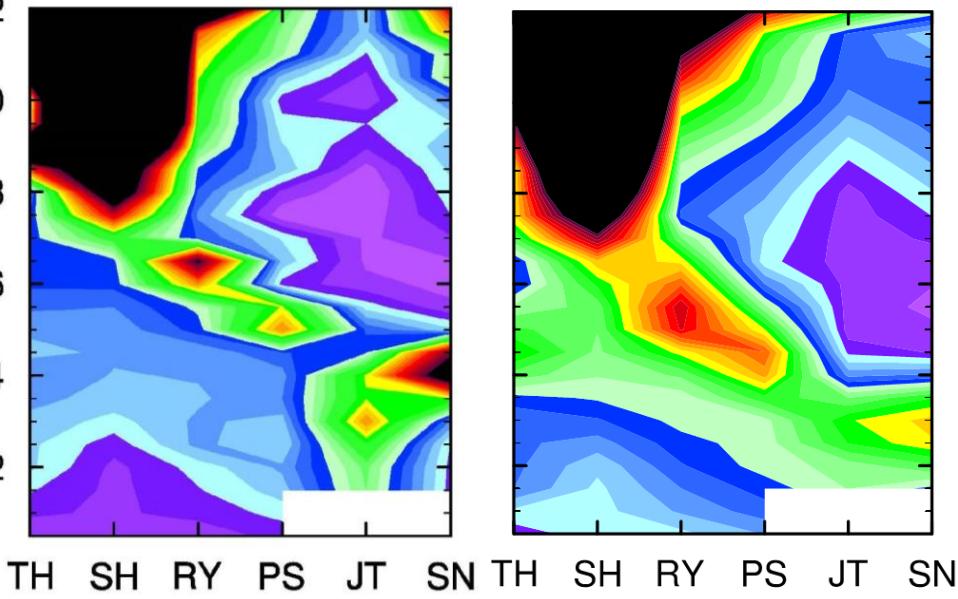
27-May-2010, 21:00UTC



Ozonesondes
(May 28)



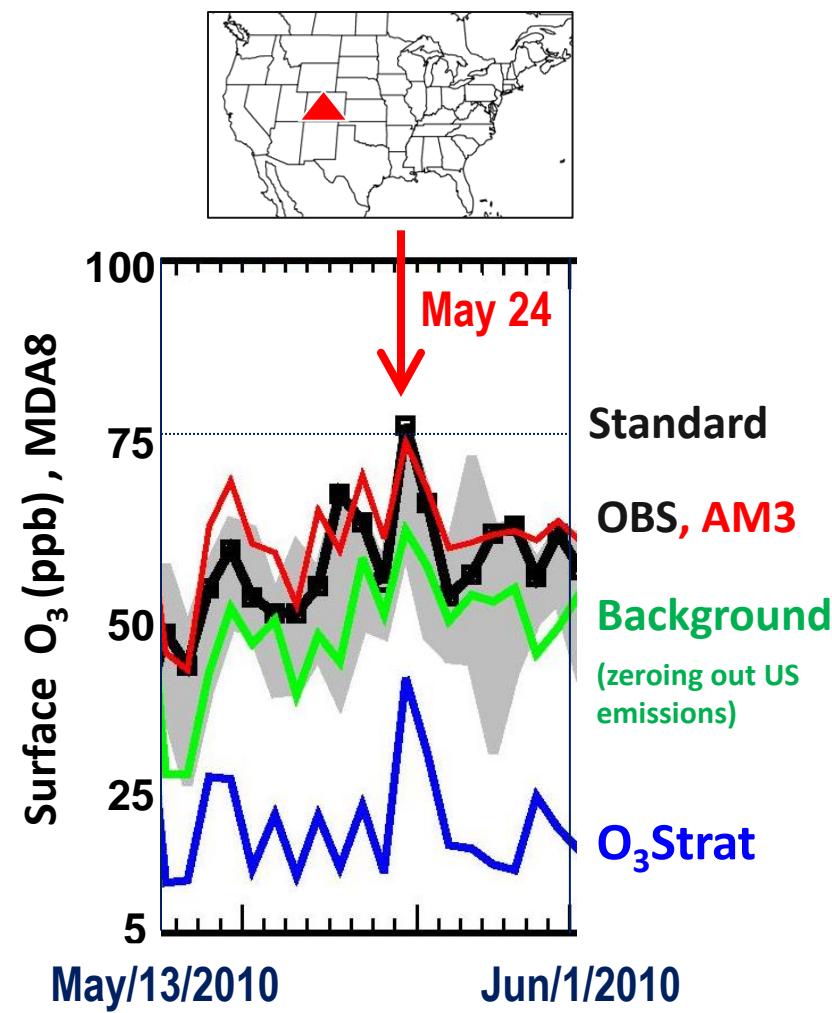
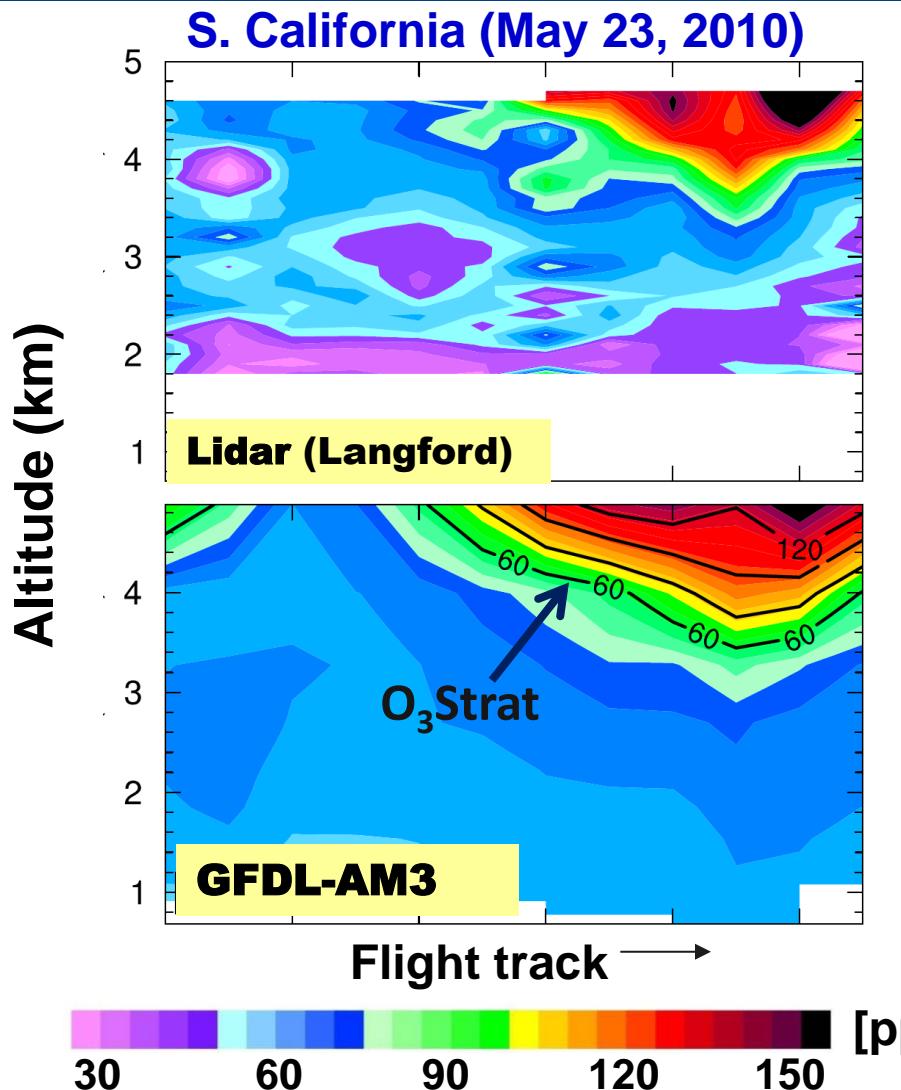
GFDL-AM3
(~50x50 km²)



- GFDL-AM3 captures observed vertical structure
- Deep mixing depths in late spring facilitate transport of FT ozone to the surface

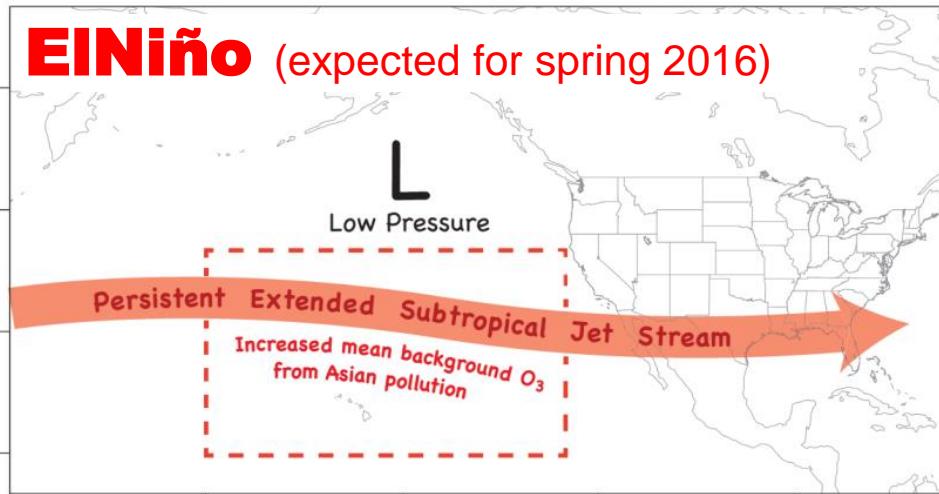


Stratospheric intrusions can push surface O₃ above the U.S. national standard

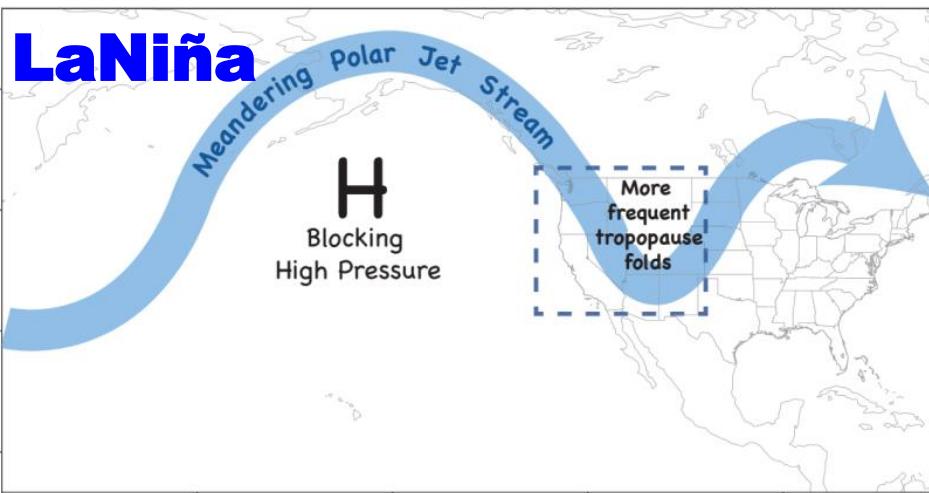


Towards a predictive understanding

El Niño (expected for spring 2016)

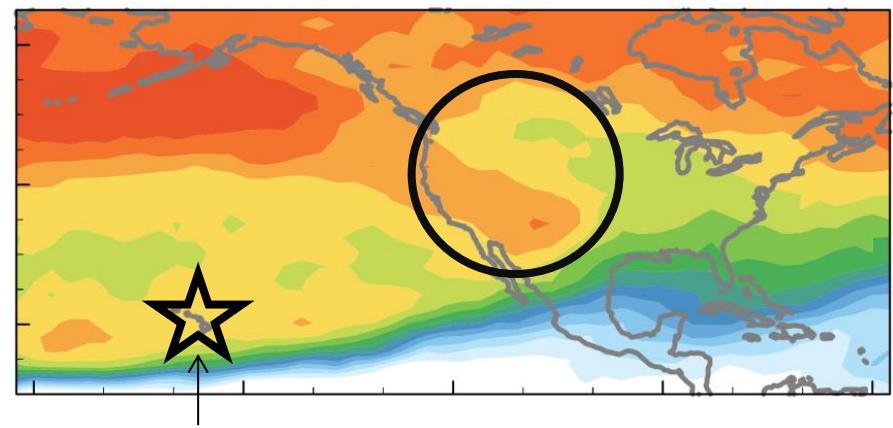


La Niña



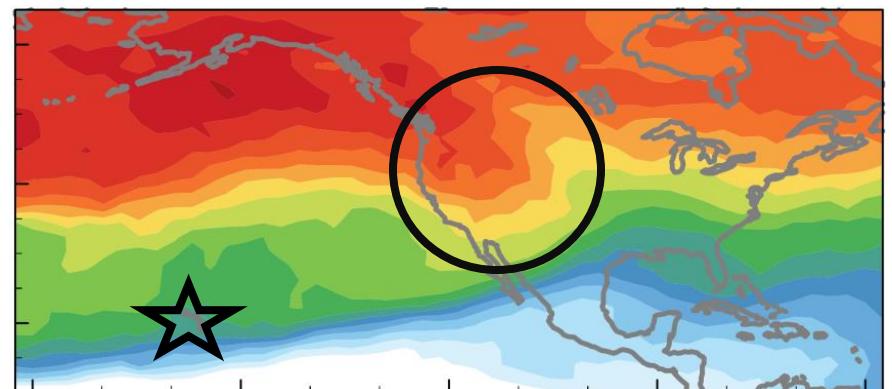
$|\text{Niño}3.4| > 1.0$; winter + spring (more O₃)

Mean background O₃ (500hPa, Apr-May)



nature
geoscience

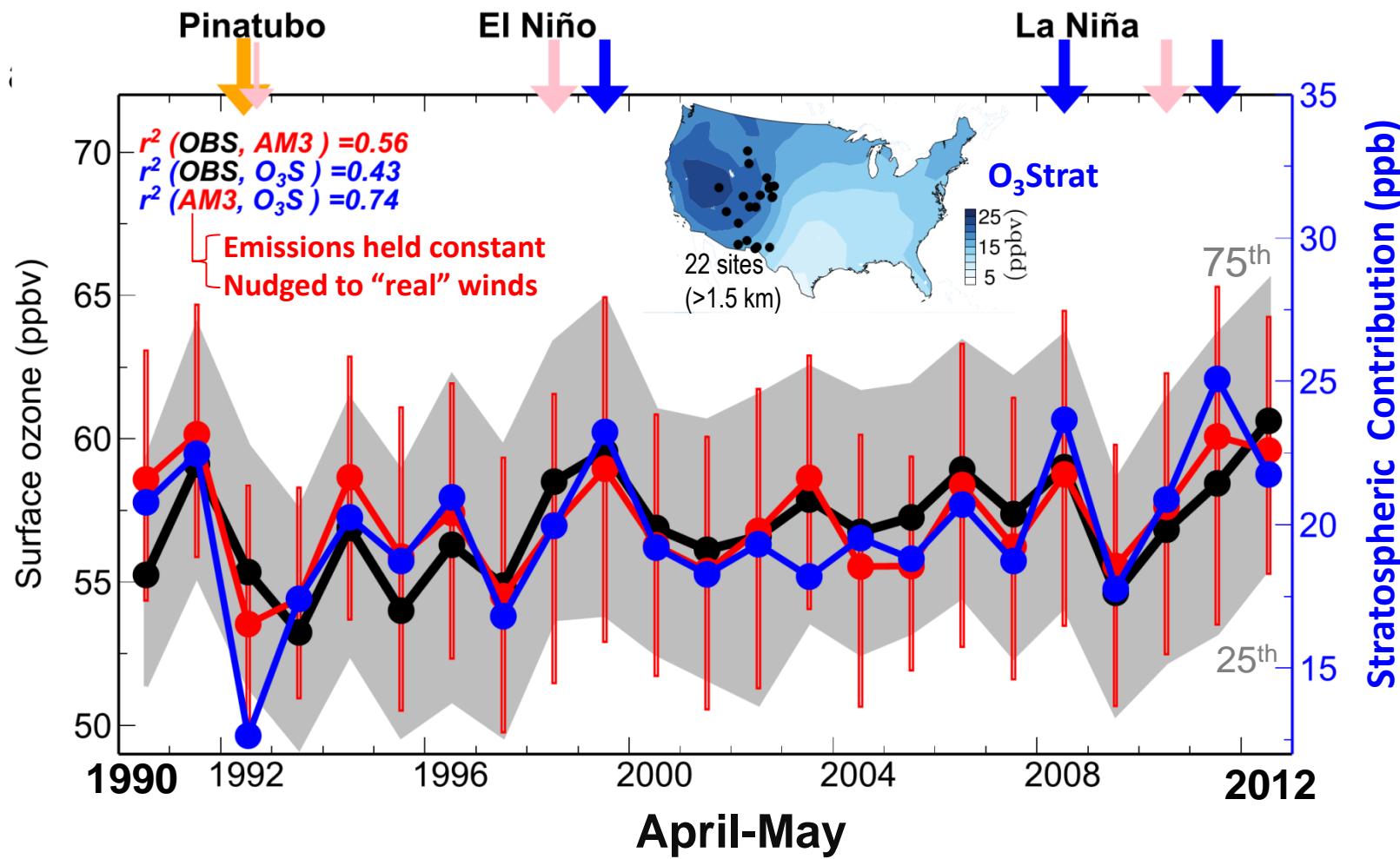
Lin et al. 2014a (Poster)



(ppb)

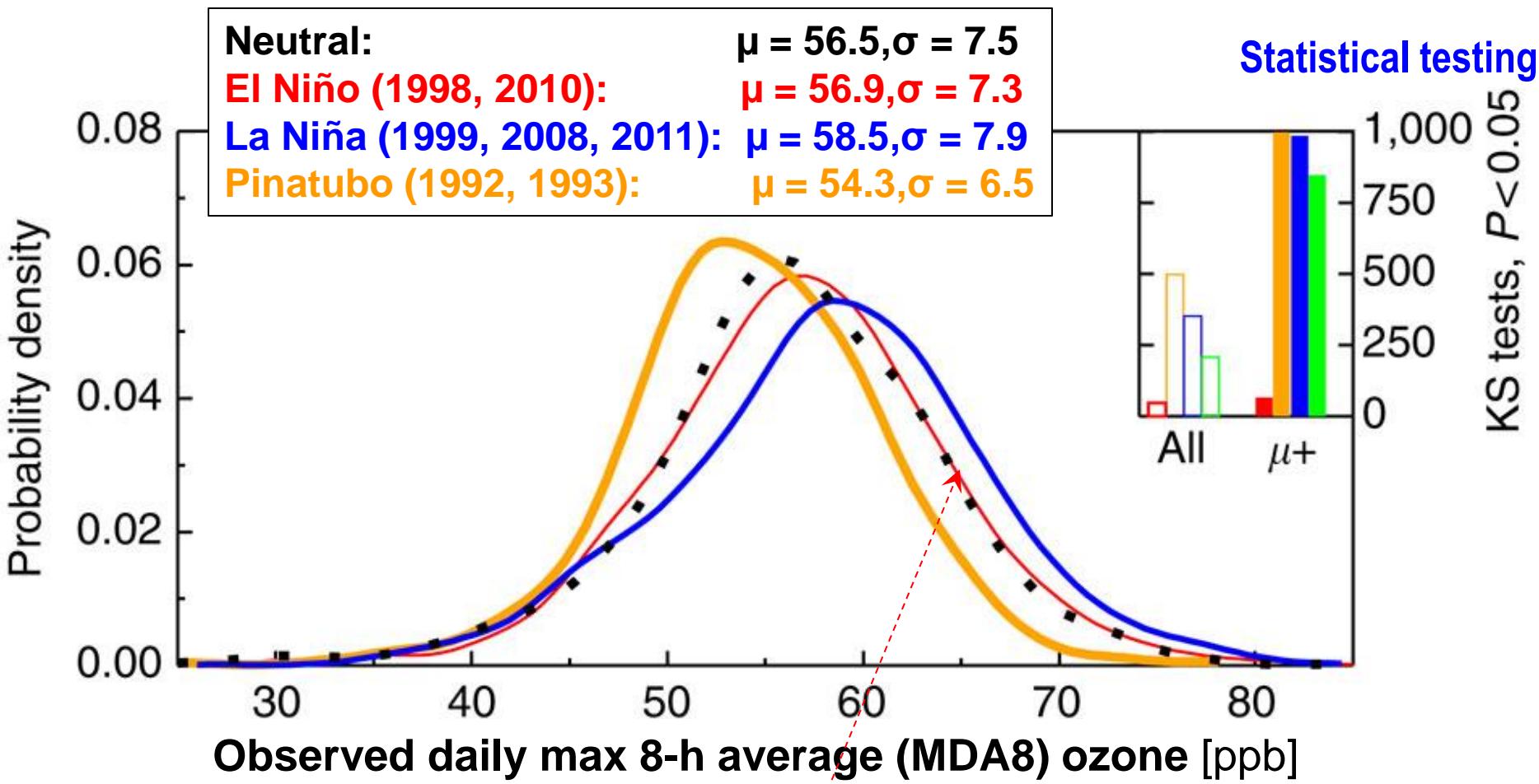
40	45	50	55	60	65	70	75	80
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Strong stratospheric influence on western US surface O₃ variability



- Stratospheric contribution is greatest during La Niña springs

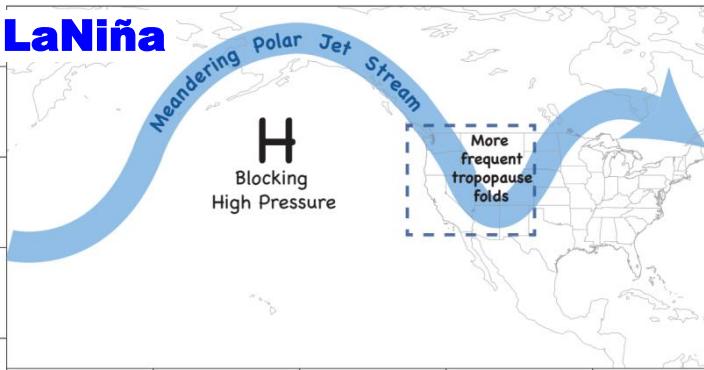
The high tail of observed surface O₃ distribution increases during La Niña springs



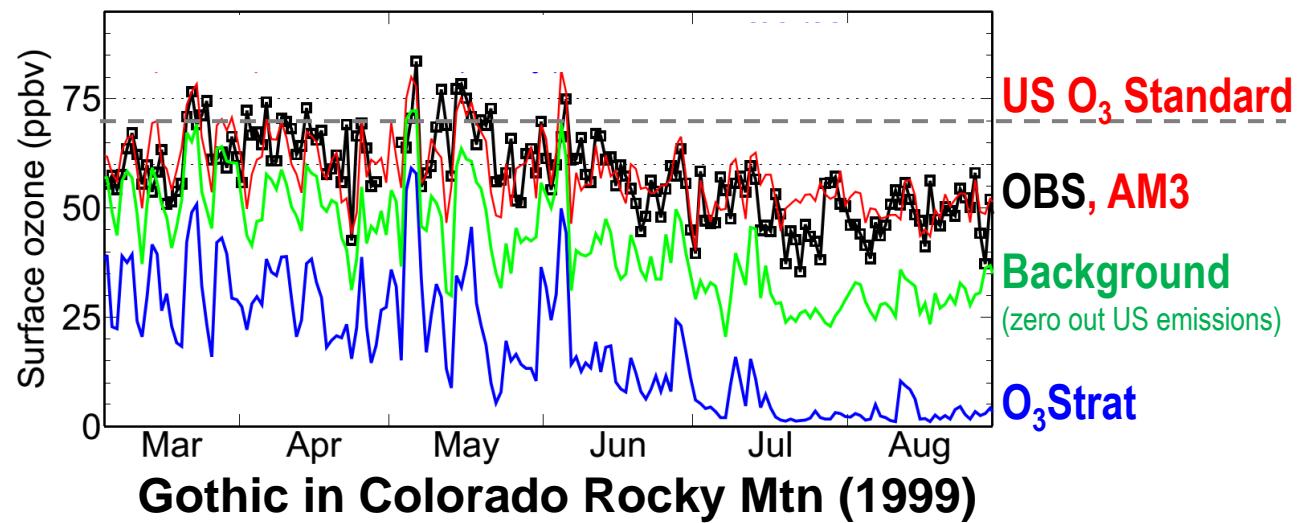
- Little difference from neutral years is discernable for El Niño conditions, despite the El Niño enhancements to mean UTLS O₃ burden [e.g. Langford1998; Bronnimann2004; Neu2014].

Developing ozone **seasonal** forecasts to aid western US air quality planning?

LaNiña



More frequent stratospheric intrusions expected for the following spring over WUS



SEASONAL FORECASTING CAN ALLOW:

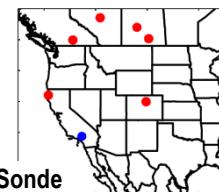
- Preparations for targeted observations aimed to identify “exceptional events”
- Improved public education to reduce health effects.

Implications for O₃ trends analysis

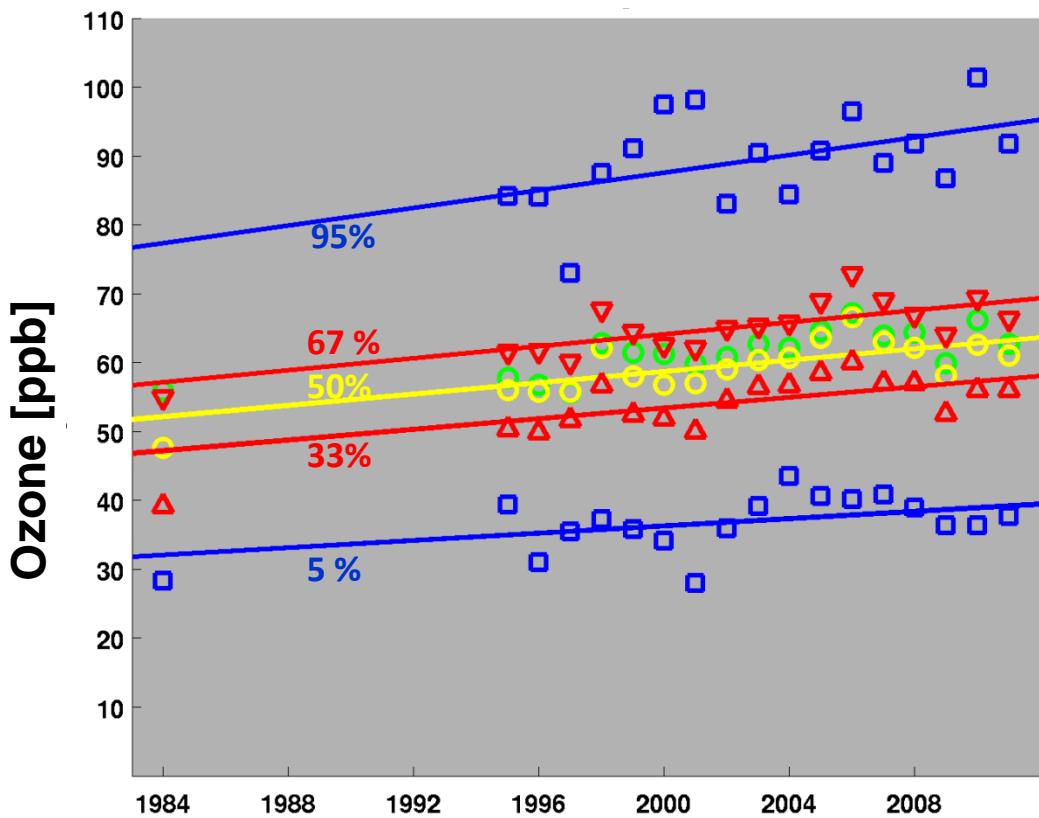
LETTERS

Increasing springtime ozone mixing ratios in the free troposphere over western North America

O. R. Cooper^{1,2}, D. D. Parrish², A. Stohl³, M. Trainer², P. Nédélec⁴, V. Thouret⁴, J. P. Cammas⁴, S. J. Oltmans², B. J. Johnson², D. Tarasick⁵, T. Leblanc⁶, I. S. McDermid⁶, D. Jaffe⁷, R. Gao², J. Stith⁸, T. Ryerson², K. Aikin^{1,2}, T. Campos⁹, A. Weinheimer⁹ & M. A. Avery¹⁰

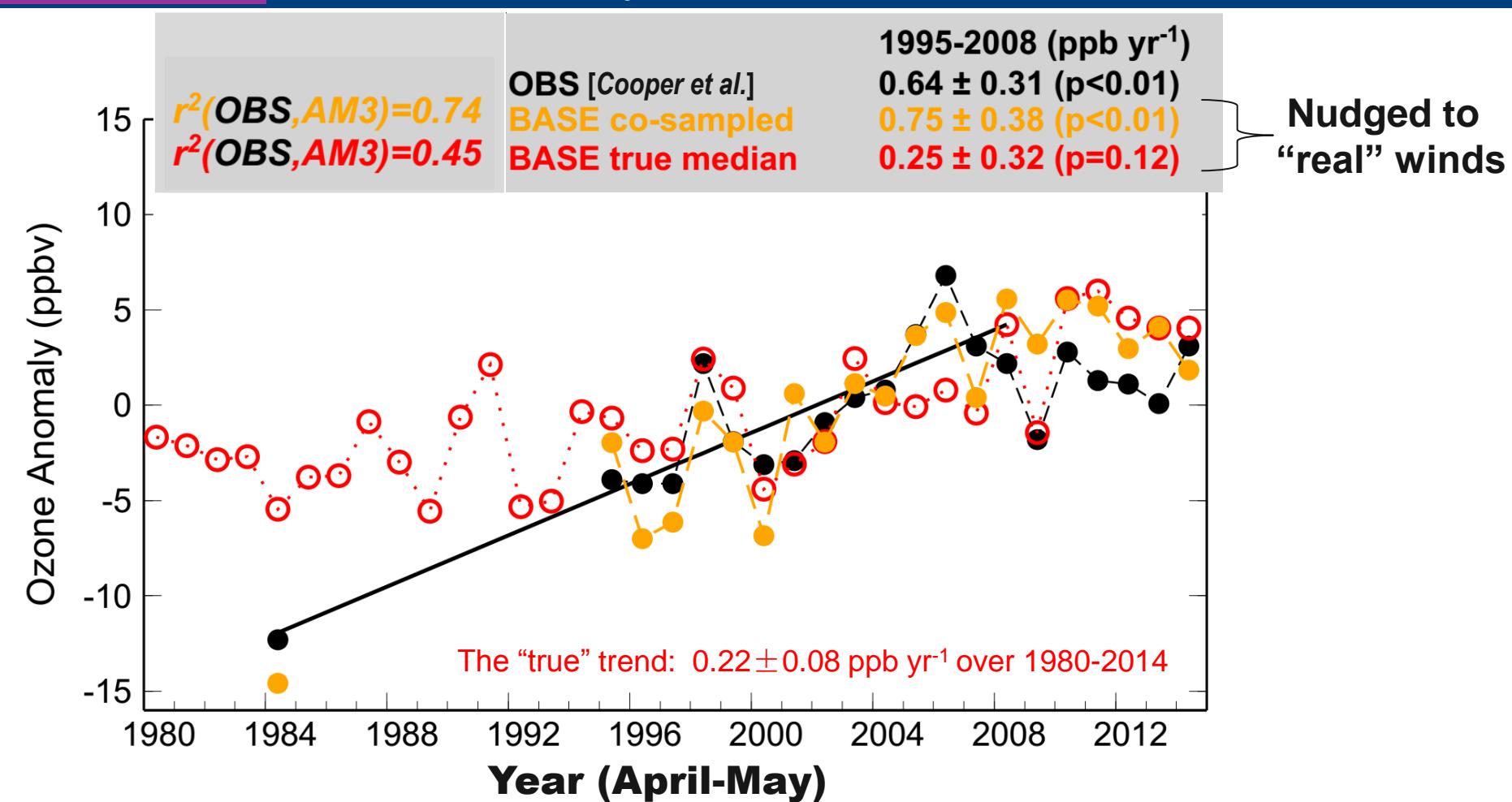


3-8 km altitude

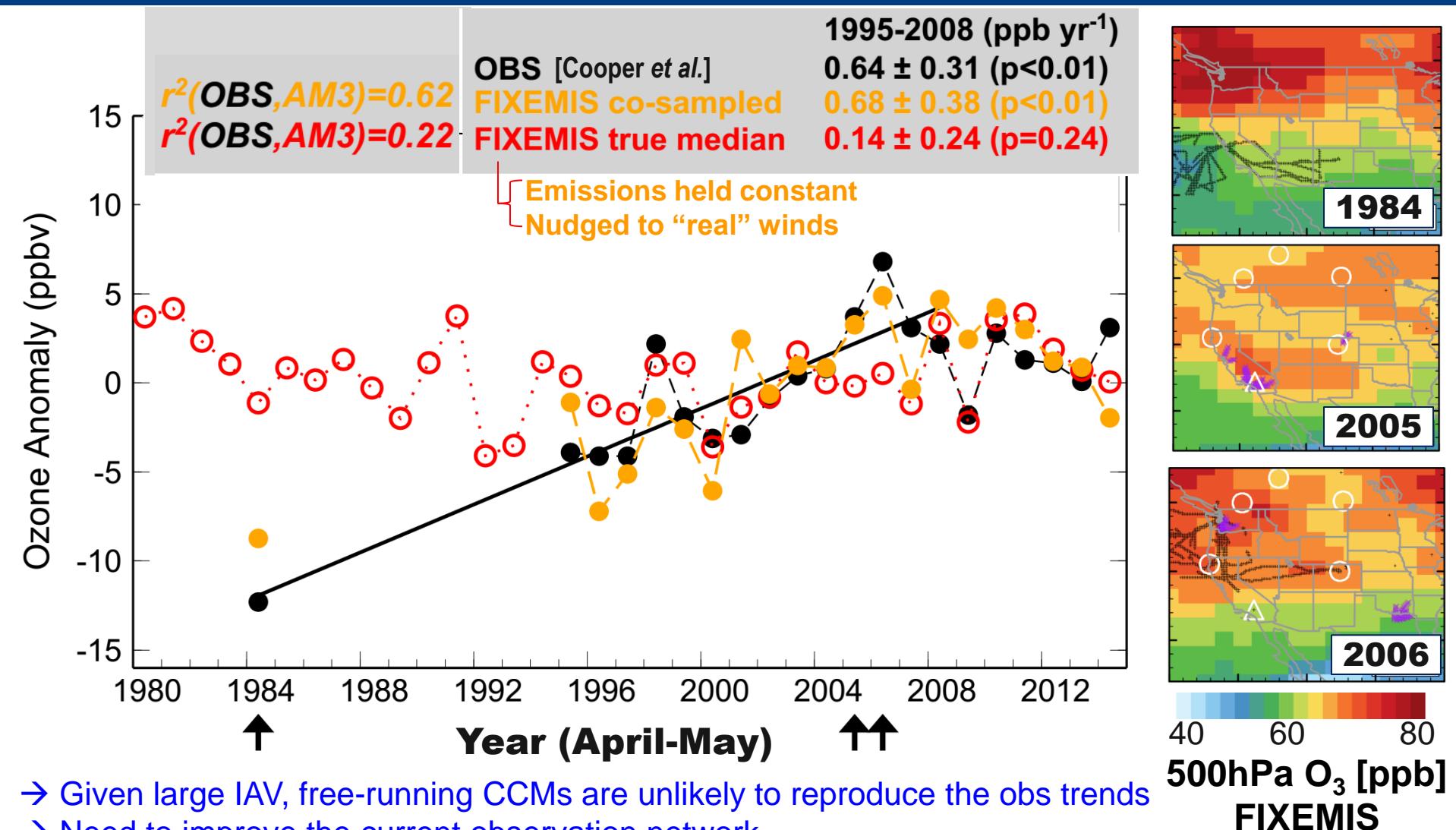


~0.6 ppbv yr⁻¹ over 1984-2008

Lamarque *et al.* [2010];
Parrish *et al.* [2014]:
Free-running CCMs capture only
<50% of observed O₃ trends

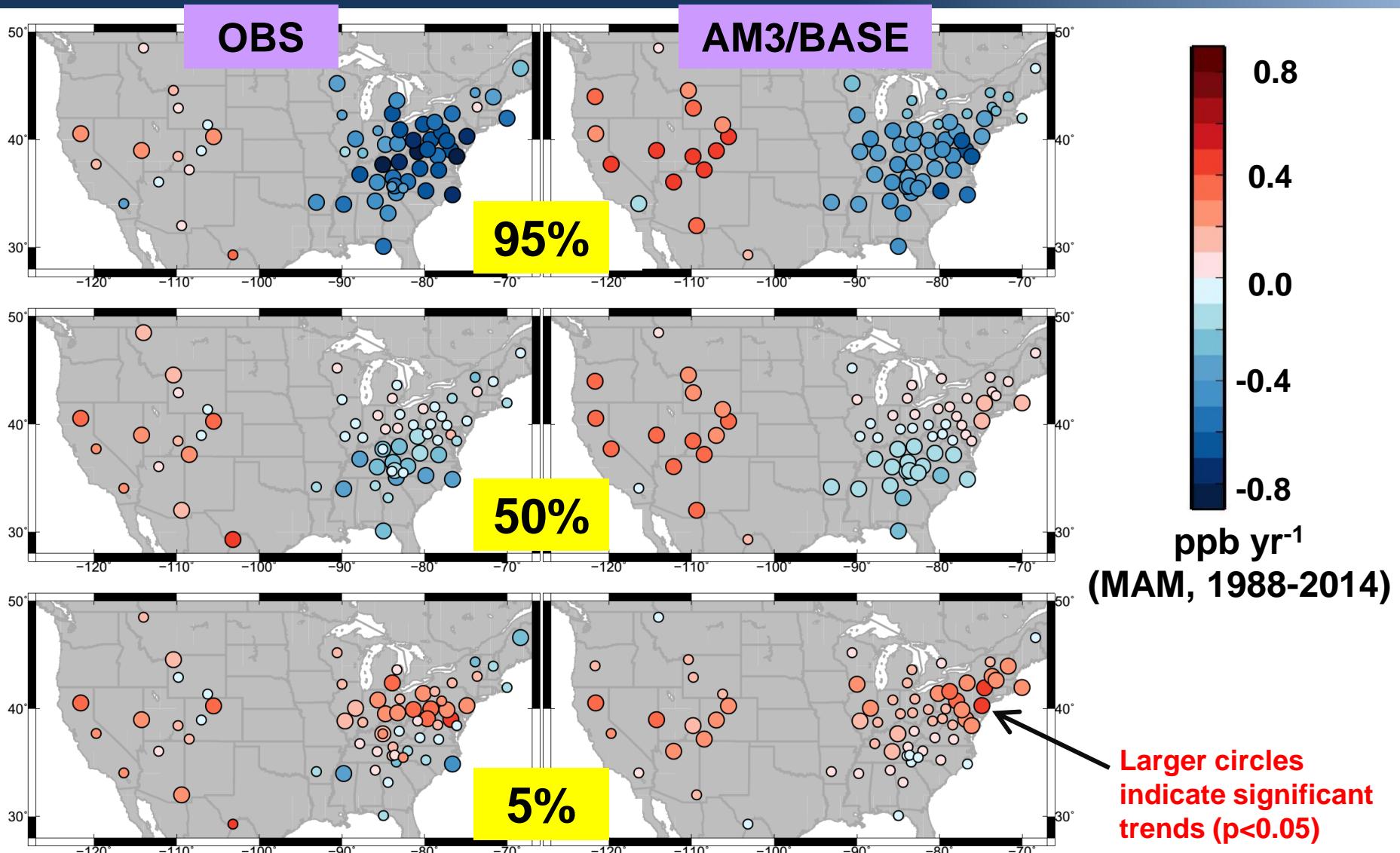
Revisiting the evidence of increasing springtime
 O_3 in the free trop over western N. America

Large meteorological variability and sparse *in-situ* sampling complicate O₃ trend estimates



Process-oriented evaluation of US surface O₃ trends

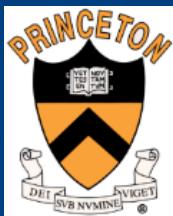
Lin, M. et al, *in prep*



WUS Mtn. Sites: model filtered to remove fresh local pollution (NACot > 67th percentile)

Concluding Remarks

- Strong stratospheric influence on WUS surface O₃ variability on daily to interannual time scales.
- Short or sparse observations, in light of large meteorological variability, can complicate trop. O₃ trends estimates.
- Must compare observed O₃ trends against hindcast simulations (as opposed to free-running CCMs).



Cooperative Institute for
Climate Science (2010-present)



NNH13ZDA001N (2014-2016)
NNX14AR47G (2014-2017)

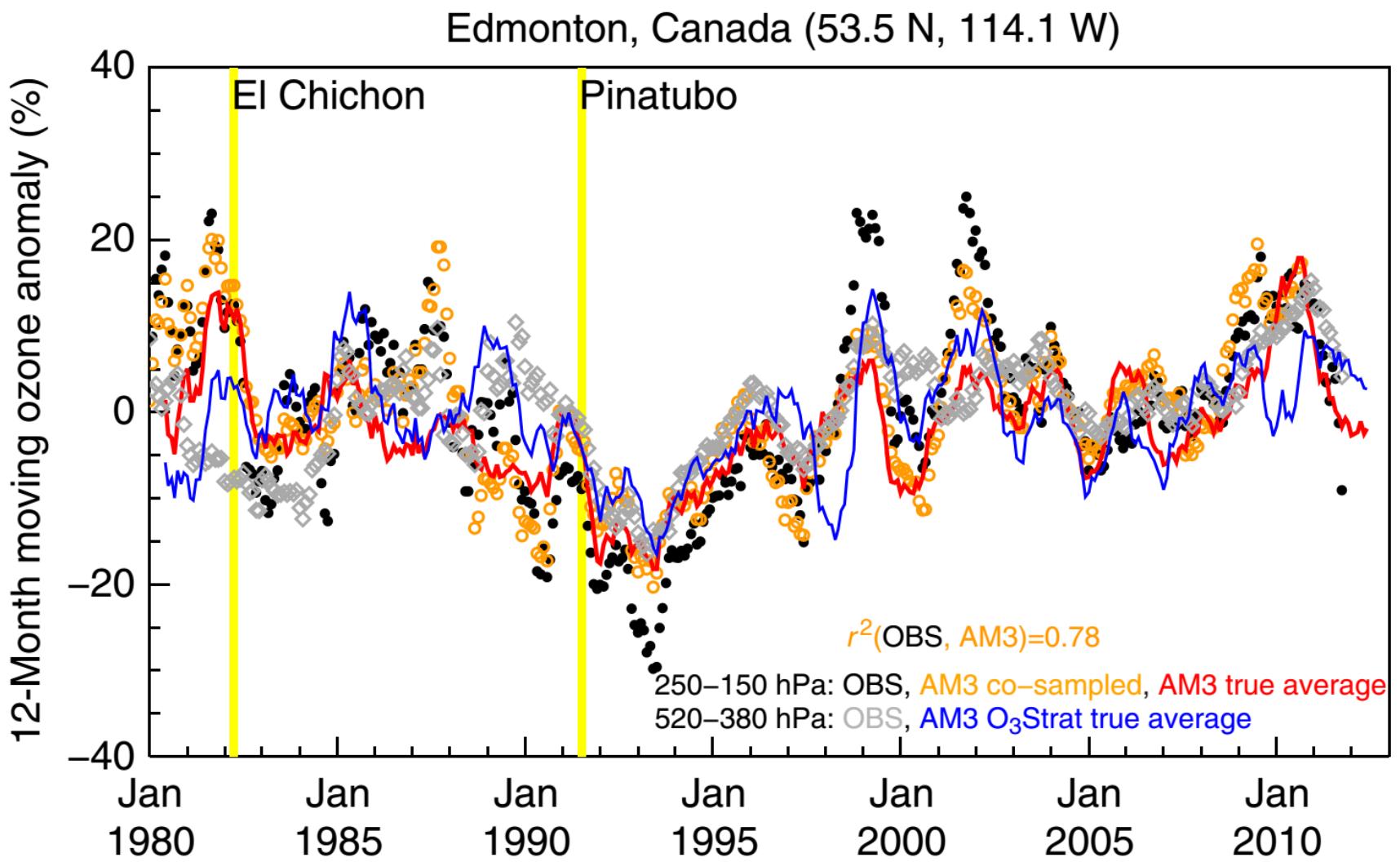


NNX12AF15G
(2011-2015)

Additional Slides for Discussions

Nudging in GFDL-AM3

- **Problems:**
 - Model top is higher than in reanalysis data
 - Nudging can introduce “noise” in tracer transport, particularly STE
 - Different transport time scale in the troposphere (several days) and the stratosphere (~1 month)
- **Approach:** Increasing nudging time scale with decreasing pressure, e.g. 6 hours at 1000 hPa, 60 hours at 100 hPa, and 600 hours at 10 hPa

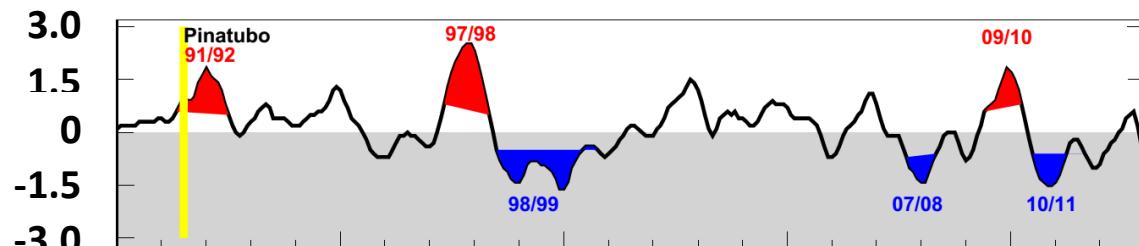


The STT influence on WUS surface O₃ variability shows little correlations with mean O₃ burdens in the UTLS

Niño 3.4 Index

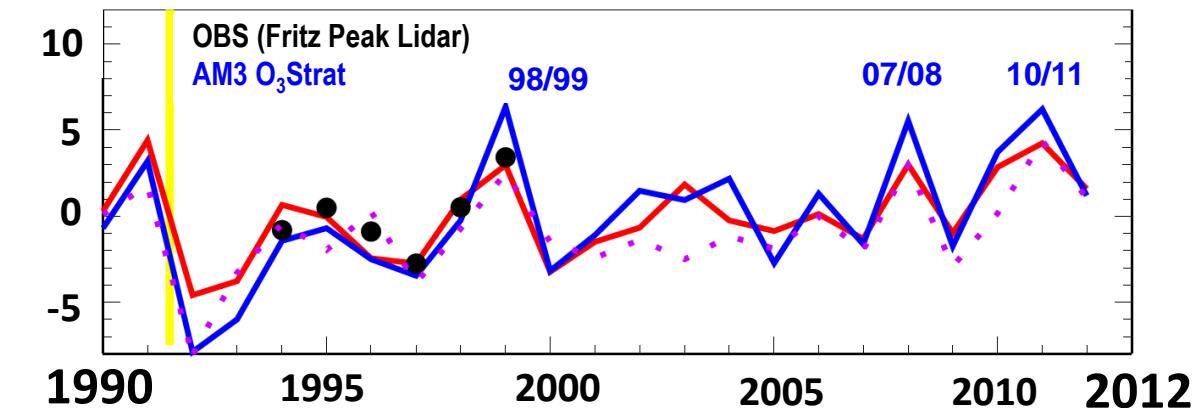
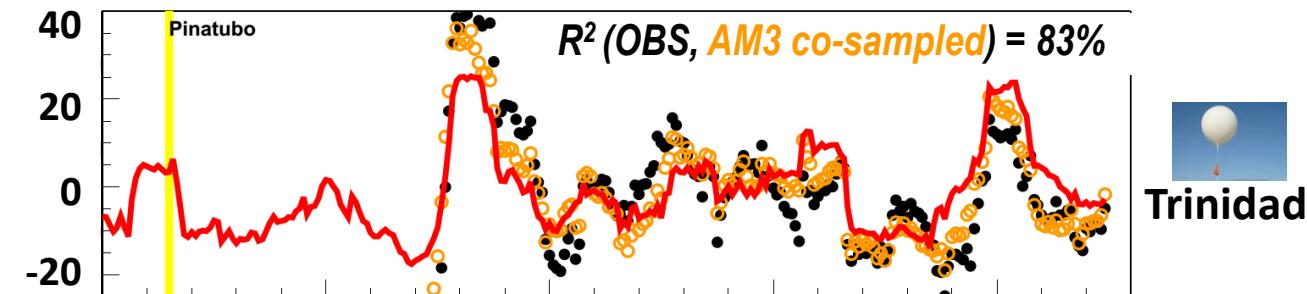
250-150hPa O₃ anomaly
(%, 12-Mon moving)

R² (UTLS, Surface) = 7%



FreeTrop & Surface O₃ anomaly (ppb, Apr-May)

R² (FreeTrop, Surface) = 74%



→ Correlating ozone at the surface or in the free-trop with that in the lower-strat is NOT necessarily a useful diagnostic